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A SIMPLE ROTARY VISCOMETER FOR THE STUDY OF ANOMALOUS VISCOUS PROPERTIES*

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ABSTRACT. A simple rotary viscometer suitable for the study of 'anomalous' viscous properties is described. It admits of easy end correction and there is no slip at the metal walls with sugar and glycerine solutions. Consistency curves of bentonite suspension, gelatin sol and starch paste representing respectively plastic, structure viscous and dilatant systems have been obtained.

In investigations on anomalous viscous properties, the shearing stresses corresponding to different rates of shear have to be measured. Rotary viscometers have the advantage over capillary viscometers that the annular space can be made small compared to the diameter of the cylinders and the velocity gradient can be made to vary over a comparatively smaller range. Further it appears from direct measurements of the velocity gradient by us that the capillary viscometer does not give true estimates of the yield value whereas the rotary viscometer does. In the simple rotary viscometer[1] described in this note the outer cylinder rotates and the torque on the inner cylinder is measured.

The new viscometer has the following features (Fig. 1) :

(*a*) The speed of an outer cylinder, A, which can be varied from 10 to 1000 rotations per minute is measured by a revolution counter, C.

(*b*) The inner cylinder, I, is suspended from a graduated torsion head, H fitted with a vernier. The position at rest of the inner cylinder is indicated by a lamp and scale arrangement (not shown in the figure). The torsion head is rotated in the opposite direction until the cylinder comes to its original

ROTARY VISCOMETER

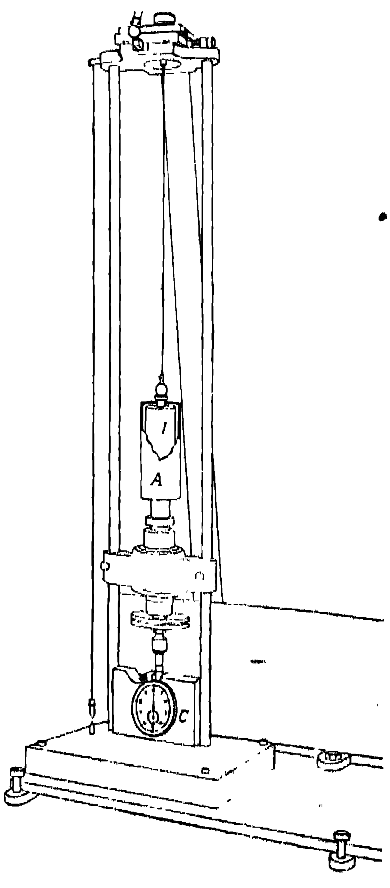

FIG.

* Communicated by the Indian Physical Society.

position of rest. The torque is read directly on the torsion head and can be measured up to 360° whereas if the deflection of light on the graduated scale[2] alone were utilised only a small torque could be measured.

(*c*) The torsion head, H, is fitted with a centering device and a plumb line and levelling screws ensure a vertical setting of the apparatus.

(*d*) The inner cylinder is about 9 cm. long and the end effect is small. The correction for this with simple liquids is of the order of 5%. Guard rings[3] have not been used as they might cause complications for non-Newtonian liquids.

(*e*) The radius of the outer cylinder is 2.017 cm. and those of the inner cylinders are 1.886, 1.792, 1.650 and 1.495 cms. The width of the annular space is thus small compared to the radii of the cylinders. This consideration is of importance in liquids where the rate of shear does not change linearly with the shearing stress.

(*f*) The apparatus has been made heavy enough to minimise vibrations.

The shearing stress, F, and the rate of shear, dv/dz, are given by the following relations :

$$F = \frac{M}{2\pi L R_1^2} \qquad \dots \quad (1)$$

$$dv/dz = \frac{2\Omega R_2^2}{R_2^2 - R_1^2} \qquad \dots \quad (2)$$

where Ω is the angular velocity ; R_2 and R_1 the radii of the outer and inner cylinders ; L the length of the latter immersed in the liquid ; $M = \tau\theta$ where θ is the torque and τ the moment of torsional couple. τ is as usual determined by the method of oscillation.

End effect is equivalent to a virtual increase in the length, L, of the inner cylinder and equation (1) can be written in the form

$$F = \frac{M}{2\pi(L + l) R_1^2} \qquad \dots \quad (3)$$

l has been determined by the method of Searle[4] with a 40% sugar solution and a 39% glycerine solution. Results are given in figures 2, 3 and 4 and in table I.

The viscosity of a 56% glycerine solution obtained with the different inner cylinders was found to be 5.5, 5.6, 5.7 and 5.6 centipoises respectively.

Liquids showing anomalous viscous properties are often classified in four groups,[6] namely (*i*) plastic, (*ii*) structure viscous, (*iii*) dilatant and (*iv*) thixotropic. Some systems show a behaviour which combines the features of more than one of the above typical classes. Plastic systems are characterised by a yield

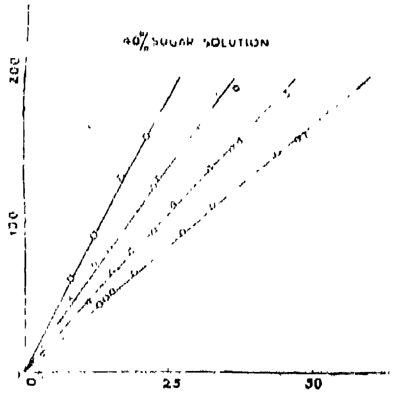

FIG. 2

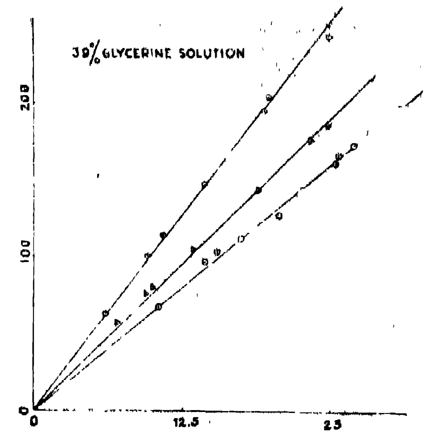

FIG. 3

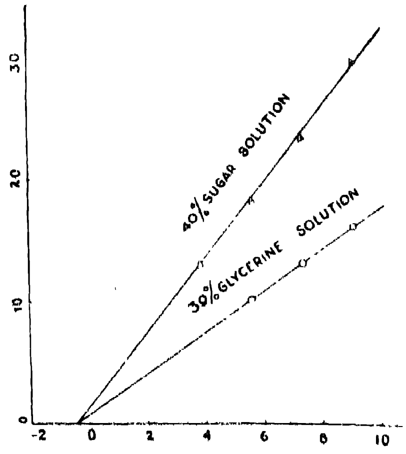

FIG. 4

value and straight consistency curves at sufficiently high rates of shear. Structure viscous bodies have a constant viscosity at low rates of shear but at higher rates the ratio between the shearing stress and the rate of shear gradually decreases. Dilatant suspensions have also a constant viscosity at low rates of shear but in contrast to the structure viscous system the ratio between the shearing stress and the rate of shear gradually increases at higher rates of shear. In thixotropic systems shearing stress at a particular rate of shear changes with time. Consistency curves which show the relationship between the rate of shear and shearing stress of the first three types of systems are represented respectively by a bentonite suspension, a gelatin sol[7] and a starch paste.[7] These have been obtained by the rotary viscometer described above and are shown in figs. 5, 6 and 7. Curves for thixotropic systems obtained by this viscometer will be described elsewhere.

TABLE I

End correction for the Rotary Viscometer

$R_1 = 1.792$ cm. ; $R_2 = 2.017$ cm. ; l (from fig. 4) $= 0.5$ cm.

Length of the inner cylinder immersed in the solution (cm.)	40 per cent. sugar solution η (centipoise) Temp. 29°C.		39 per cent. glycerine solution η (centipoise) Temp 31°C.	
	obs	corr	obs.	corr.
3.85	5.14	4.55	—	—
5.6	4.96	4.65	2.72	2.50
7.35	4.85	4.54	2.69	2.52
9.1	4.90	4.75	2.66	2.52
		mean 4.60		mean 2.51
		from standard data 4.56		2.55

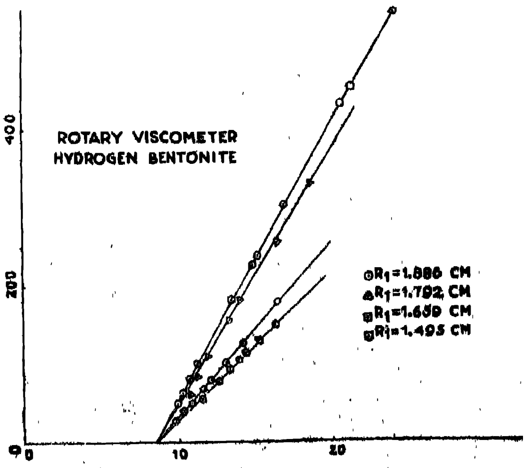

FIG. 5

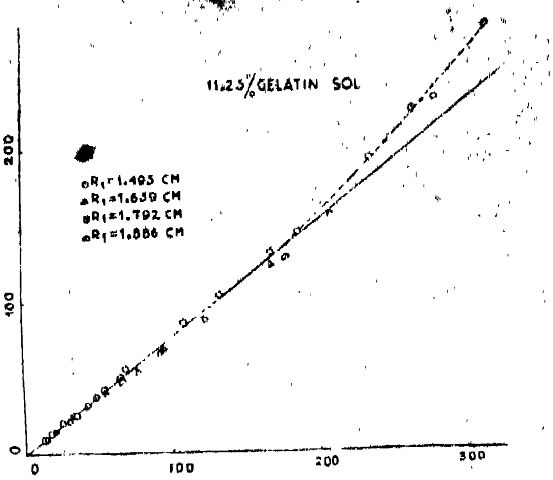

Fig. 6

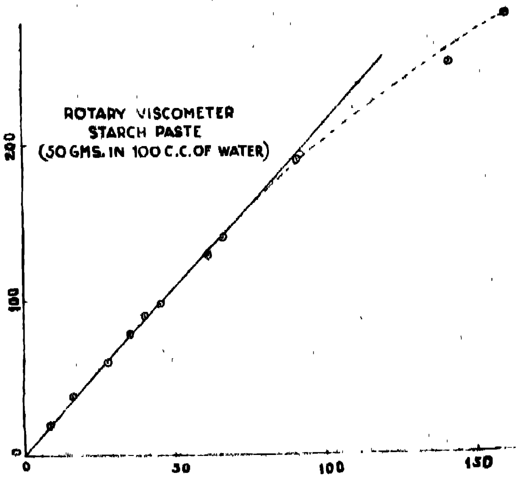

Fig. 7

The rotary viscometer described in this note has been found convenient for rapid measurements with non-Newtonian liquids.

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R E F E R E N C E S

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2 See reference 1, p. 231.
3 Hatschek, *The Viscosity of Liquids*, 53 (1928)
4 Searle, *Proc. Cambridge Phil. Soc.*, **16**, 600 (1912).
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6 Houwink, *Elasticity, Plasticity and Structure of Matter*, 10 (1937).
7 Measurements by Mr. R. P. Pal.